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Notes on four weevils in the tribe Cionini (Coleoptera: Curculionidae) associated with *Scrophularia nodosa* L. (Scrophulariaceae)

Part I: Biology and ecology of the weevils

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Abstract. The biology of the curculionids *Cionus hortulanus*, *C. scrophulariae*, *C. tuberculosus*, and *Cleopus pulchellus*, all associated with *Scrophularia nodosa*, is described. All developmental stages are registered. Figures demonstrate the life-cycle of the weevils; observations on the behaviour are mentioned. The chronological succession is demonstrated by curves of emergence. Parasitoid records are given.

Key words. *Cionus* spp., *Cleopus pulchellus*, Coleoptera, Curculionidae, phytophagous insects, *Scrophularia nodosa*.

Introduction

In contrast to the internal larval feeding, usual for curculionids, the yellow, slug-like larvae of the tribe Cionini are oligophagous, external feeders of some Scrophulariaceae. Around Kiel (northern Germany) *Scrophularia nodosa* and *S. aquatica* are the main host plants of both the adults and the larval stages of *Cionus hortulanus* (Geoff.), *C. scrophulariae* (L.), *C. tuberculosus* (Scop.) and *Cleopus pulchellus* (Herbst). The anatomy and morphology of these figwort weevils and preliminary notes on their biology have been described at the end of the last century; the results were presented in a monograph by Wingelmüller (1937). Scherf (1964) described the bionomy and morphology of the larval stages. Brief biological notes on some species were given by Cawthra (1957) for Scotland. More recently, Cunningham (1974, 1979) and Read (1976, 1977) studied the biology of some Cionini in England.

This paper is based on a study of the field ecology of all phytophagous insect species feeding on *S. nodosa* in Sleswick-Holstein. The biology of the parasitoids associated with the weevils and their influence on the hosts will be presented in the second part of this paper.

Material and Methods

Host plant: *Scrophularia nodosa* is a perennial and overwinters as a nodular, horizontal rhizome. At the end of April, the glandular stems grow to a height of 40—100 cm, exceptionally to 150 cm. The glabrous leaves have a short petiole and a serrated margin. About 50 purple-brown flowers develop from the end of June onwards in stalked panicles. The fruits are broadly ovoid capsules containing some hundred small, black seeds. *S. nodosa* tissues contain several flavones and glycosides which seem to be feeding deterrents. Only some phytophagous specialists accept *S. nodosa* as food source; occasionally a few polyphagous insects are also to be found. *S. nodosa* is not common, but its distribution covers the whole of Europe and parts of Asia. In northern Germany it occurs along shores, river banks, and in scrubs, but mainly in wet, nitrogen-rich forests. It is often associated with stinging nettle, *Urtica dioica*.

Field experiments: Weevil material was collected from the end of April to the end of October 1986. Plants standing on clearings were not attacked. Therefore, all four sampling areas were moist, shaded forests (mainly beech) in the vicinity of Kiel (10° East, 54° North). The sampling sites were controlled at weekly intervals. Observations on the copulation behaviour and oviposition were made in the field. The feeding damage caused by the weevils was determined as well as details of their life-cycle and biology. The cocoons, which the weevils spin for pupation, were collected quantitatively, and reared individually in small glass tubes, closed with moist cellulose paper. The emergence was controlled daily. The weevils emerging were marked with fluorescence powder and released at selected sites for recapture experiments.

Laboratory rearings: For oviposition experiments, some *Cleopus pulchellus* and *Cionus tuberculosus* adults were kept in Petri-dishes on moist filter paper. They were supplied daily with 3—4 fresh leaves of *S. nodosa*. The eggs laid and the number of egg cavities prepared were recorded at intervals of 24 hours. Laboratory oviposition by *C. scrophulariae* and *C. hortulanus* could not be studied, because these species lay their eggs into the buds, which decay very fast under laboratory conditions.

First instar larvae of all species were collected in the field and reared individually in Petri-dishes under constant conditions (20°C, 16 h light), to determine the duration of the developmental stages of each of the four species. The number of instars was determined by measuring the width of the head capsule as defined by the distance of the stemmata under a stereo-microscope. Living larvae of the different species cannot easily be separated. Thus the length and width of cocoons were measured in order to discriminate between the species, especially to make correct host records for the parasitoids emerging from the cocoons.

Biology of the species investigated

Cleopus pulchellus (Herbst)

Eggs: After hibernation, maturation, and copulation the females lay their eggs in cavities which are made at random at various places on the leaf, excluding the venes. To form egg-cavities the female eats a hole from the lower surface through the epidermis and excavates the mesophyll as far as its rostrum reaches. The upper and lower epidermis is not punctured. After finishing the cavity the female turns around and introduces the ovipositor through the hole. One to five eggs are laid into one cavity. The delicate eggs are semitransparent, yellow-white and oblong (the morphometric data are presented in Tab. 1). The cavity is not sealed. The time for building the cavity and for oviposition takes between 55 to 95 minutes. A field collected female laid about 286 eggs during a period of 23 days, i. e. on average almost 12 eggs per day. A mean number of 6.6 cavities were prepared per day, containing 1.8 eggs on average.

Larval instars: The creamy whitish first instar larvae of *C. pulchellus* hatch after 6—7 days, the egg membrane is not consumed. The dark-brown head capsule appears about one day before hatching, the typical mucous body-cover of the Cionini forms shortly after the larvae start feeding. The larvae feed aggregated at the lower surface of the leaves, removing the epidermis and the mesophyll despising the venes. The upper epidermis remains entire, the feeding holes have the appearance of windows. At this stage the colouration changes to yellow; larvae consuming the purple lips of the flowers appear in that colour. The third and last larval instars cause most of the damage, they also produce "window" holes, leaving the upper epidermis untouched. Feeding is mainly on leaves, but scraping on buds and stems also occurs.

Table 1: Morphometric data of the developmental stages and duration of development.

	Cleopus pulchellus	*Cionus scrophulariae*	*Cionus tuberculosus*
		Egg	
Length (mm) ± S. E. (mm)	0.76 ±0.05	0.85 ±0.05	0.82 ±0.06
Width (mm) ± S. E. (mm)	0.39 ±0.03	0.45 ±0.05	0.42 ±0.04
Number measured	48	33	100
Duration of development (days at 20° C)	6−7	6−8	5−8
		First larval instar	
Diameter of head capsule (mm) ± S. E. (mm)*)	0.22 ±0.01	0.28 ±0.02	0.29 ±0.03
Number measured	22	24	30
Duration of development (days at 20° C)	4−5	4−6	3−4
		Second larval instar	
Diameter of head capsule (mm) ± S. E. (mm)*)	0.33 ±0.02	0.43 ±0.01	0.46 ±0.02
Number measured	24	18	30
Duration of development (days at 20° C)	2−4	2−4	2−3
		Third larval instar	
Diameter of head capsule (mm) ± S. E. (mm)*)	0.48 ±0.03	0.72 ±0.02	0.72 ±0.03
Number measured	54	15	30
Duration of development (days at 20° C)	6−12	7−10	5−8
		Cocoon	
Length (mm) ± S. E. (mm)	3.4 ±0.16	5.7 ±0.25	4.6 ±0.26
Width (mm) ± S. E. (mm)	2.3 ±0.11	4.5 ±0.34	3.5 ±0.18
Number measured	100	100	100
Duration of pupal development (days at 20° C)	10−14	9−13	8−11

*) Distance between larval stemmata

Feeding on the stems injures the vascular system and causes premature dessication of attacked plants.

While some activity of the larvae was observed during daytime, an observation during night-time (at 1 a. m.) revealed night activity and feeding of all immature instars of all Cionini. The adult weevils tend to hide during the day, and seem to be more active during night, too.

Pupae: For pupation *C. pulchellus* larvae descent on the main stem and spin an oval, amber cocoon a few millimetres below the soil surface. A few cocoons were formed on the lower leaf surface. For emergence the adults bite a circular opening at one end of the cocoon. A lid joined by a "hinge" tucks up before the young weevils emerge.

Adults: *C. pulchellus* is the smallest Cionini species (2.9−3.3 mm in length) occurring on *S. nodosa*. The adults are brown with black and white longitudinal stripes on the elytrae. The young adults make their way through the soil to the surface and

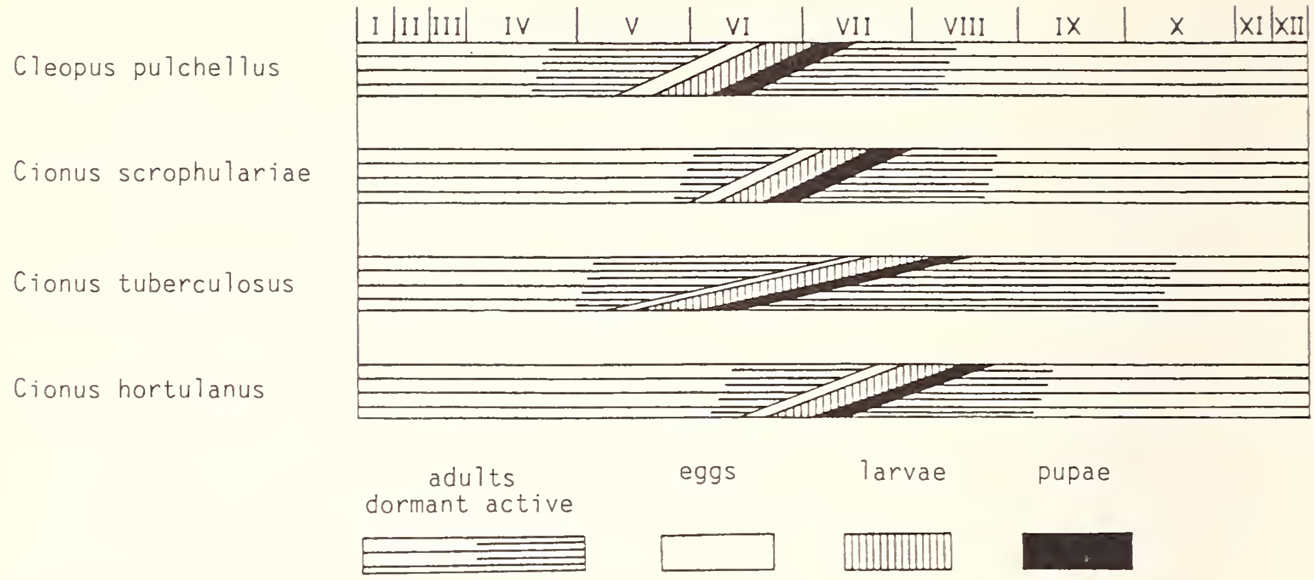


Fig. 1: Phenology of the Cionini species investigated.

start feeding in late June. They feed on *S. nodosa* until mid-August when they leave the plants for their hibernation quarters (Fig. 1).

It is very likely that the imagines of all Cionini species hibernate. The overwintering sites are not known, but, presumably, hibernation takes place below the bark of trees or in the leaflitter. In the laboratory, Cunningham (1979) used containers with moist sawdust of cork to keep imagines of *C. hortulanus* during winter. The overwintered *C. pulchellus* adults appear again at the end of April when *S. nodosa* shoots begin to grow. After a preoviposition period of about 10 days pairing starts. The male, apparently attracted by pheromones, touches the female with its antennae. For mating it climbs on the elytrae of the female; copulation can last for more than 30 minutes. If the female is not ready for mating it shakes its abdomen vigorously until the male leaves. After successful mating the female soon starts with oviposition. The total life-span for *C. pulchellus*, as for the other Cionini, is about one year. In northern Germany *C. pulchellus* was found to have only one generation per year, in warmer regions two generations might be possible (Read 1976).

Parasitoids: No parasitoids of the eggs or adults of any Cionini species were found. As a larval-pupal parasitoid of *C. pulchellus* a few individuals of the gregarious eulophid *Entedon zanara* (Walker) were reared.

Cionus scrophulariae (Linné)

Eggs: The overwintering adults appear again from the beginning of June to mid-July. They need some days for maturation feeding; the mating behaviour of all *Cionus* species is analogous to *C. pulchellus*. The females lay their eggs exclusively into a cavity gnawn into developing flower buds. A small hole is eaten at the base of the bud, then the female excavates an oblong cavity removing a portion of the ovary as deep as its rostrum is long. Afterwards the female of *C. scrophulariae* turns around and deposits the delicate, yellow eggs (size see Tab. 1). After oviposition the hole is sealed with a plug of secrete or, possibly, feces, or both (Read 1977). This plug is first translucent and soft but dries out and hardens within a day, often changing

to dark green or brown. Field observations indicate that two to three hours are needed for building the cavity, oviposition and sealing. Field collected flower buds contained on average 4—9 eggs within each cavity, with normally only one cavity per bud.

Larval instars: After hatching the first instar larvae start feeding on the content of the buds. Later, they eat through the bud wall, and start to consume externally various parts of the plant, i. e. leaves, buds and seed heads. The early stages avoid eating the small venes of the leaves, just feeding the top layer of cells on the lower side of the leaves. Third instar larvae were observed to feed on venes, mid-rips and main stems as well, but predominately on buds and seed heads. The larvae feeding on buds and seed heads change their colouration, probably caused by plant contents, to reddish-brown or purple. They produce large, open holes on leaves and destroy most of the seed heads of the attacked plants. Several plants attacked by *C. scrophulariae* produced new, but smaller buds later (in September). However, these seed heads contain only a few seeds.

Pupae: Mature third instar *C. scrophulariae* larvae tend to climb the upper parts of the plants. They loose their mucous covering, the boundaries of the segments can now be seen for the first time. They spin oval yellowish-brown cocoons which look in size and colour like ripening seed heads. Up to 35 individuals per plant were found in clusters between the buds. Occasionally some cocoons were found at the under side of the leaves. Details on the construction of the cocoon can be found in Cox (1951).

In the cocoons the heads of the developing adults are pointing downwards. After the last moult the young weevils harden inside the cocoon. They bite with their mandibles, perhaps supported by an enzyme produced by the rostrum, a circular opening into the bottom of the cocoons, the lid tucks up, and the young adults crawl onto the plant.

Adults: The young adults can be found between the end of July to mid-August. *C. scrophulariae* is the largest Cionini species, its length being about 4.5 mm with no difference between the sexes. The basic colour is greyish brown covered with white and black hairs and scales, the whole upper thorax bears yellow brown hairs. The front and apex of the elytrae bear a black spot surrounded by white hairs; these are the characteristical marks of *Cionus* species. The adults feed on leaves and stems producing round open holes often surrounded by green frass. Like *Cleopus*, the *Cionus* species overwinter as adults. However, so far no overwintering sites have been found. *C. scrophulariae* has a single generation a year.

Scott (1937) noticed *C. scrophulariae* feeding on the South African plant *Phygelius capensis* and Williams (1974) found some adults feeding on a *Buddleia* sp. However, these plants are no natural hosts but their acceptance by this oligophagous weevil species indicates a close relationship of these plant genera.

Parasitoids: Larvae of *C. scrophulariae* are heavily attacked by the gregarious eulophid *Entedon zanara*. At a single collection site cocoons were attacked by *Scambus buolianae* (Hartig), a polyphagous ichneumonid known as a primary parasitoid of the pupae of several tortricids.

Cionus tuberculosus (Scopoli)

Eggs: After hibernation as adult lasting till May, a maturation period, and mating, the females of *C. tuberculosus* prepare egg cavities in the petioles and mid-rips of the leaves. Feeding through a small hole they produce an oblong cavity. After excavation the females turn around and lay 1—4 eggs. Afterwards the hole is plugged with secrete which is apparently produced by the anal segment (Read 1977). At first the plug is yellowish-red; when it hardens it becomes translucent. The females need about 90 minutes for cavity building, oviposition, and sealing.

A field collected female laid about 165 eggs during a period of 39 days. The oval eggs are white and translucent. The chorion is delicate, and ruptures easily. On average 4.2 eggs were laid daily with 1.5 cavities built. A mean of 2.75 eggs were found per cavity. The female used in the experiment was collected in mid-May, it appears that it had already laid some eggs before collection. Read (1977) reports a higher fecundity. However, he used a single female, too, and the range of eggs laid may vary between the individuals of a species.

Larval instars: The yellowish-white first instar larvae are more convex than larvae of the other *Cionus* species. After hatching they eat a hole into the wall of the egg cavity and make their way to the lower side of the leaves. Feeding of the early stages occurs as scratches on the top layer of cells, mainly from the under surface of the leaves. Second and third instars eat round holes into the leaves, but avoid to consume thicker venes. Stems, buds and seed heads are also attacked, but leaves are clearly preferred. While the data of the head capsule width (Tab. 1) indicate that *C. tuberculosus* is the largest *Cionus* species, measurements of the body length and weight as well as the cocoon size show that *C. scrophulariae* is about one third larger.

Pupae: The mature larvae of *C. tuberculosus* loose their hyaline coating, and spin with their mouth parts ovoid cocoons on the lower side of the leaves. After some time the cocoons harden and their colour turns to amber. Pupation occurs within 1—3 days. The pupae are first white and active. Some days later melanisation begins. Shortly before emergence the pupae are completely coloured; they moult and the imagines harden inside the cocoons. Upon emergence the young adults bite a circular opening in the cocoon. The exuviae of the last instars and the pupae remain in the cocoon.

Adults: the adults of *C. tuberculosus* have a length of about 4.0 mm. Their elytrae are more convex than those of the other *Cionus* species. The basic colouration is brown, with white and black hairs and scales in longitudinal lines on the elytrae. Both sides of the thorax are covered with reddish brown hairs.

Between mid-June to early October, the young adults feed on the leaves and stems producing round, open holes. The imagines hibernate. Some individuals survived until the following summer when kept at 2 °C in a container with bark material and moist sawdust, verifying the life- span of about one year. At the beginning of May, when *S. nodosa* growth starts, the overwintered adults appear again. Laboratory rearings showed that most of these females oviposit until July, but some start with oviposition later, and egg laying occurs until September. Some individuals stop oviposition in June, resuming it in August. However, there is always only one genera-

tion a year, none of the freshly emerged females oviposited before hibernation which indicates a diapause requirement before maturation. The following spring, after a feeding period of about ten days, the ovarioles develop and pairing and oviposition begins. It is not easy to distinguish the sexes externally; dissected males of the different species can be recognised by the form of their penes (description by Wingelmüller 1937).

Parasitoids: The larvae and cocoons of *C. hortulanus* and *C. tuberculosus* cannot be separated because of their morphological and ecological similarity and equal size. Therefore, the parasitoids of both species have to be discussed together.

Both host species are attacked by a gregarious, internal larval-pupal parasitoid, the eulophid *Entedon cionobius* (Thomson). Also common is the solitary, external pteromalid *Habrocytus cioni* (Thomson) which successfully competes with the eulophid. Of much lower incidence are three indeterminable *Gelis* spp. and the polyphagous ichneumonids *Itoplectis alternans* (Grav.) and *Agrothereutes abbreviator* (Fabr.).

Cionus hortulanus Geoffrey

Eggs: According to Cunningham (1979), one or two yellow oval eggs are laid within the perianth of the buds. However, in captivity supplied only with leaves of *S. nodosa*, oviposition was observed freely on the container walls.

Larval instars: Besides several *Scrophularia* species, this figwort weevil also attacks various *Verbascum* species, especially *V. nigrum* L. (Grandi 1929; Cunningham 1974; Heidecker 1985). In the laboratory, fed with leaves of *S. nodosa*, the mortality of early instars was quite high. Hence, nothing can be said about the biology of the larval instars.

Cunningham (1979) noted that the muscous, hyaline covering of the Cionini should protect the animals from desiccation. In addition, it should be a protection against cannibalism which this author reported for all figwort weevils. However, although many individuals of different instars were reared together in Petri-dishes, cannibalism was never observed, even when the plant material was nearly completely consumed.

Pupae: Cunningham (1979) described the building of a cocoon for pupation as follows: "On reaching full size the larvae produce chitinous strands from the peritrophic membranes, which are voided and mixed with glutinous material of the hyaline coat. This flows around the larva, covering the ventral surface for the first time. The larva shapes the coat into an ovoid cocoon which hardens and tans to amber colour." In the field, some cocoons of *C. hortulanus* were found on the lower side of the leaves, but most of them were in between the buds and seed heads. The cocoons are 4.8 $\pm$0.25 mm long, their width is 3.6 $\pm$0.17 mm (n = 50).

Adults: Cunningham (1979) suspects that an enzymatic secretion is applied by the tip of the rostrum for the openinmg of the cocoon, but Read (1977) describes the opening only with the use of the mandibles. The freshly emerged, young imagines are to be found between the end of June to mid-September. *C. hortulanus* is supposed to hibernate as adult. After overwintering the adults appear again between mid-

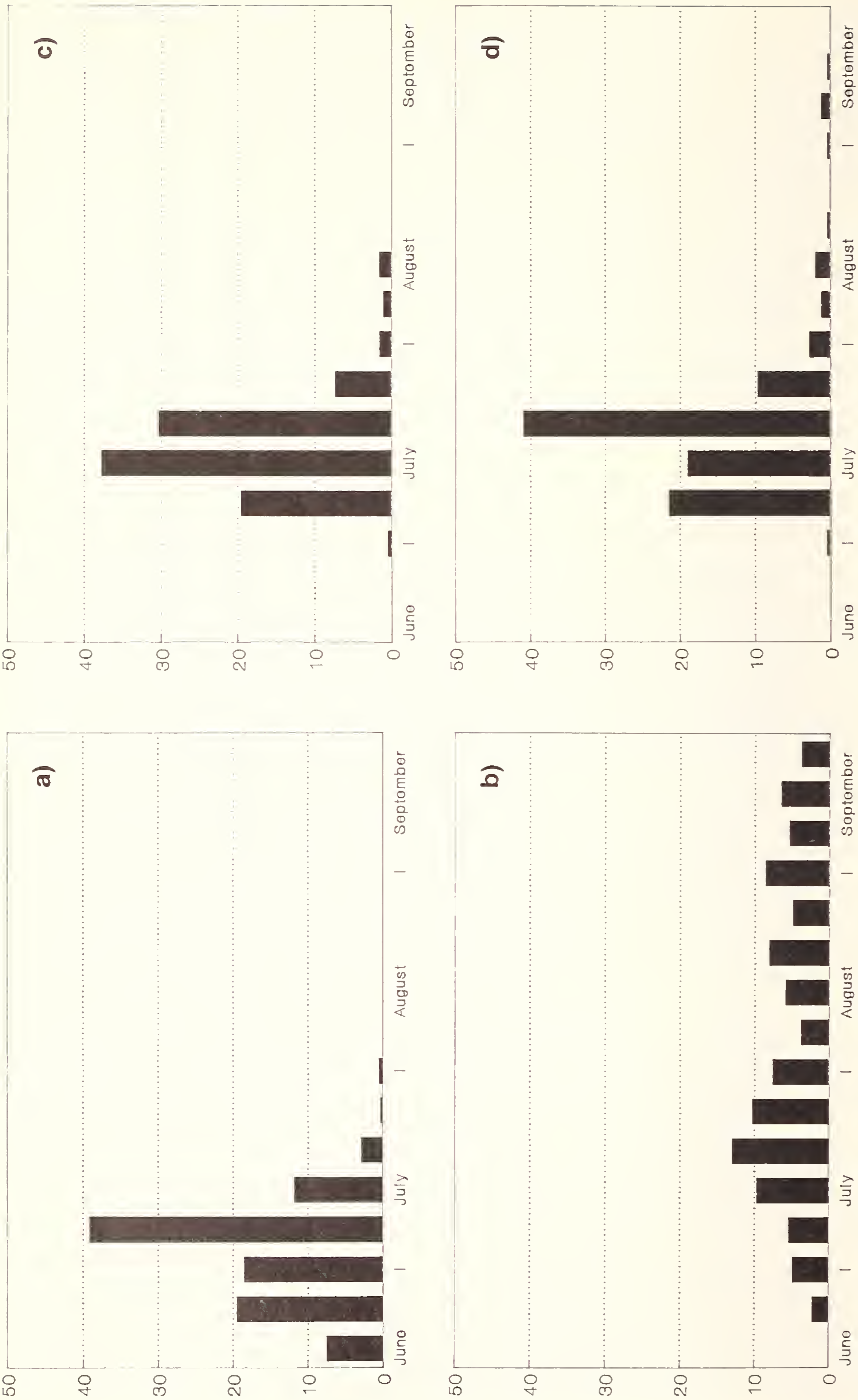


Fig. 2: a) Emergence of young adults of *Cl. pulchellus* (in %).
b) Emergence of young adults of *Ci. scrophulariae* (in %).
c) Emergence of young adults of *Ci. tuberculosus* (in %).
d) Emergence of young adults of *Ci. hortulanus* (in %).

June to August. After a pre-oviposition period of about one week they start egg laying.

C. hortulanus has the length of *C. tuberculosus* (4.0 mm) but is more oblong. The basic colouration is a greyish-green, spotted with white and black scales. On the elytrae they have the two characteristic marks of the *Cionus* species. While in northern Germany one generation was found, Cunningham (1979) reported the occurrence of two generations for England, but this seems rather doubtful.

Parasitoids: As the living larvae and the cocoons of *C. hortulanus* and *C. tuberculosus* cannot be differentiated, the parasitoids of both host species were mentioned in the previous section.

Ecological aspects of the weevil species investigated

Phenology: To assess the chronological succession of the weevils the results of emergence of all sampling sites were combined. The emergence of the young adults of the weevil species occurs separated, each species corresponding to a normal distribution (Fig. 2a—d).

The new generation of *Cleopus pulchellus* appears as earliest with a peak in the beginning of July (Fig. 2a). In the middle of July *Cionus scrophulariae* has its peak of emergence (Fig. 2b), and a little later *C. hortulanus* appears, a species which dominated at the end of July and is present in low numbers until September (Fig. 2d). *C. tuberculosus* is present all over the season, from the end of June to mid-September, reaching no real peak. The long period of its appearance and two waves in the emergence data (Fig. 2c) suggest the existence of two generations a year, as described for England by Read (1977). However, the laboratory rearings showed a very scattered oviposition period of this species and no oviposition of the young adults. This proves the occurrence of only one generation of *C. tuberculosus* in northern Germany, with an overlap of the parent- with their daughter-generation (Fig. 1).

Migration: 50 individuals of each species, marked with fluorescence powder were released at a defined site. At intervals of one week all adults available were collected on plants of *S. nodosa* in circular distances of 100 m, 200 m, and 300 m, respectively. However, only three *Cionus scrophulariae* (6 %) and two *C. tuberculosus* (4 %) could be recollected. Four individuals were found within one week at a distance of 100 m, a single *C. tuberculosus* was captured four weeks after release at the 300 m distance. The low rate of recapture might be explained by adult mortality, but probably most of the individuals had hidden during daytime or had gone into their hibernation quarters already. Field observations indicate that the Cionini do not fly very often. However, on hot days, some individuals were observed to fly for distances of about 10 meters landing on a *Scrophularia* plant or not far from it. The adults were observed to feed more actively during night and it is possible that the Cionini have a higher flight activity at twilight hours or during the night. The migration potential of the Cionini seems to be low, they prefer to stay at their location. Thus, some plants were heavily attacked, others, standing nearby, were not infested at all.

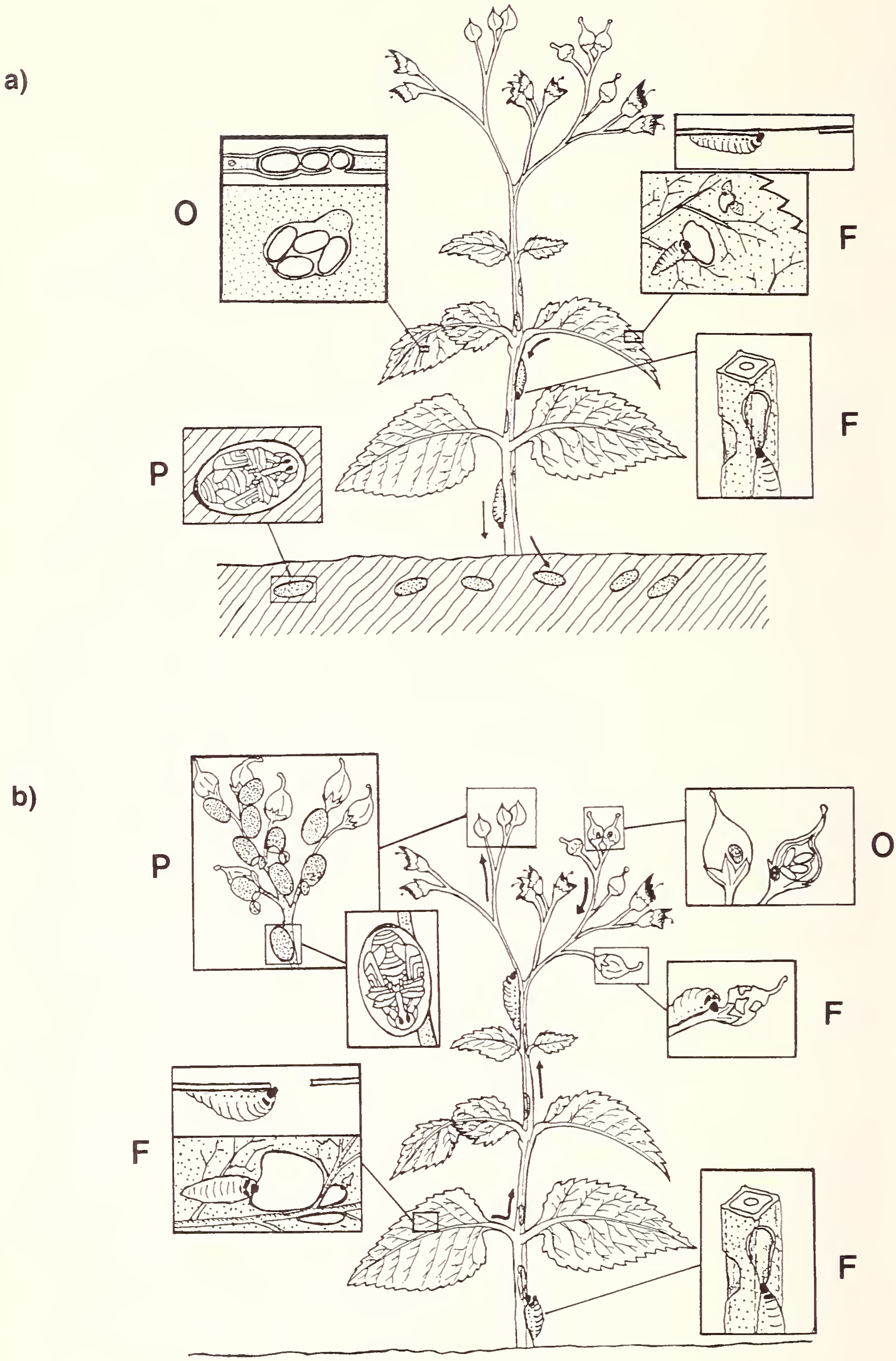
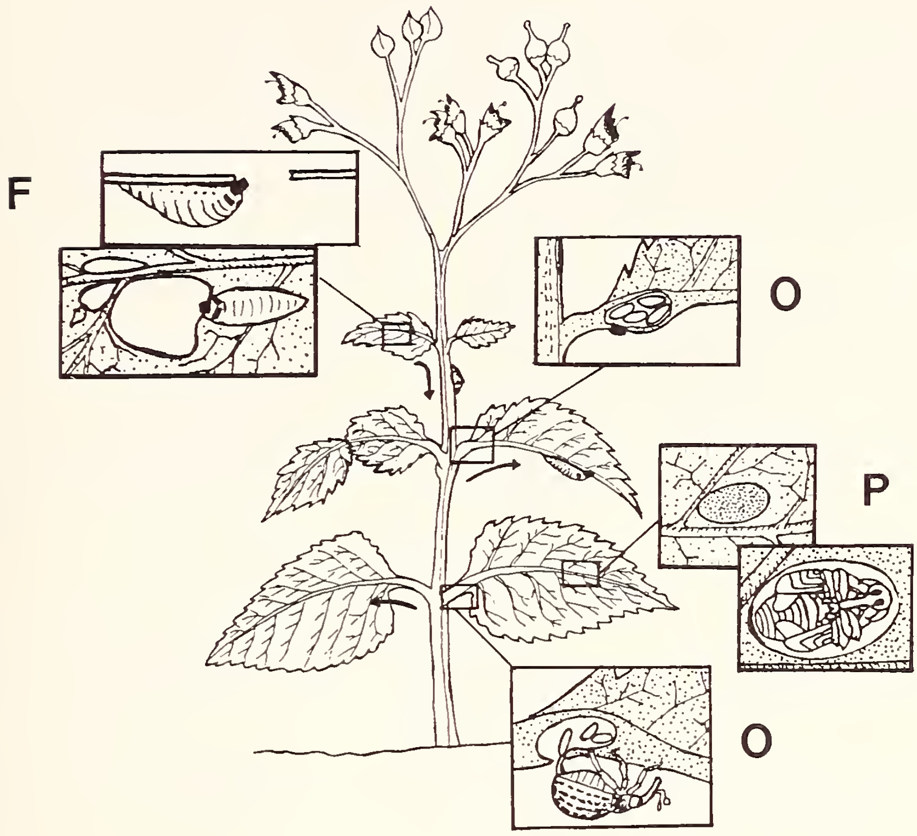
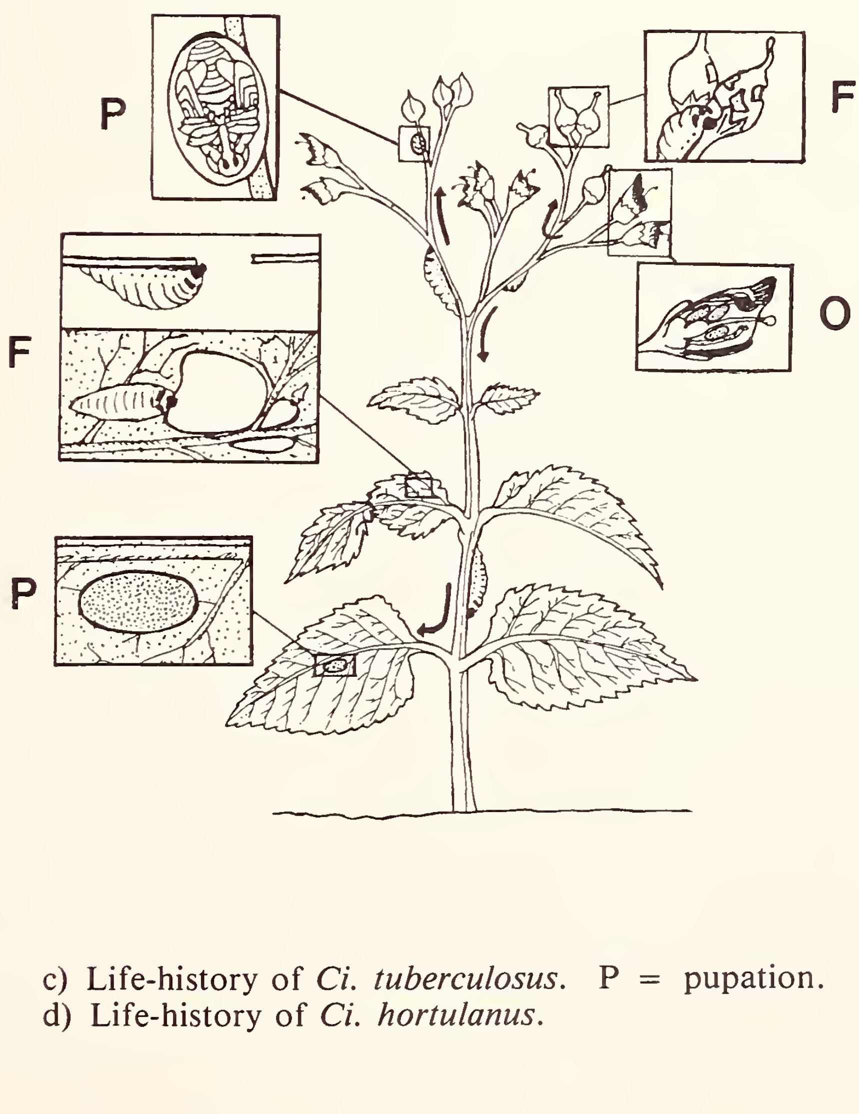


Fig. 3: a) Life-history of *Cl. pulchellus*. O = oviposition.
b) Life-history of *Ci. scrophulariae*. F = larval feeding.

c)



d)



c) Life-history of *Ci. tuberculosus*. P = pupation.
d) Life-history of *Ci. hortulanus*.

Distribution on the host plant: During their development the different life-stages of the four weevil species prefer and attack different parts of the plant (see Tab. 2; Fig. 3a, b, c, d). While there is some overlap in chronological succession, the use of different plant parts is a strategy that helps to avoid competition and to make optimal use of the food-source. If there is an overlap in the feeding habit the species that coexist do not occur at the same time (Fig. 2b, d) or in the same locality.

Table 2: Biological parameters of the Cionini.

	Cleopus pulchellus	*Cionus scrophulariae*	*Cionus tuberculosus*	*Cionus hortulanus*
Oviposition	Cavity in the leaf	Sealed cavity in the buds or seed heads	Sealed cavity in the leaf-midrips	free into the perianth
L 1	Scratches at the underside of the leaves	Scratches on the buds and seed heads	Scratches at the underside of the leaves	Scratches on the buds and seed heads
L 2	"Window"holes from the underside of the leaves	Holes on buds, seed heads and leaves	Holes in the leaves	Scratches on the buds and seed heads
L 3	"Window"holes from the underside of the leaves	Holes on buds, seed heads and leaves	Holes in the leaves	Scratches on the buds and seed heads
Pupa	Cocoons in the soil	Cocoons between the seed heads	Cocoons under the leaves	Cocoons between the seed heads
Adult	Scratches and holes at various plant parts Overwintering of the imagines in bark cracks or in the leaf-litter			

Other phytophagous insects

During early summer the four Cionini species are the most important consumers of *S. nodosa*. Besides these, only the larvae of the tenthredinid sawfly *Tenthredo scrophulariae* L. are of significance and consume most of the remaining plant material during late summer. The sawfly larvae are attacked by the internal ichneumonid parasitoid *Mesoleptidea prosoleuca* (Grav.); *Euceros serricornis* (Hal.) and an undetermined *Astiphromma* ap. were reared as ichneumonid hyper-parasitoids. The larvae of the tenthredinids *Pachyprotasis rapae* L. and *P. antennata* Klug occur sporadically on *S. nodosa*, but cause only limited damage.

Occasionally, some figworts are attacked by larvae of Lepidoptera. Low numbers of the specific noctuid *Cucullia scrophulariae* L. were collected and successfully reared. Some individuals of the polyphagous noctuids *Mamestra persicariae* L., *M. pisi* L., and some undetermined geometrids were also observed to feed and develop on *S. nodosa*.

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Zusammenfassung

Die Biologie von *Cionus hortulanus*, *C. scrophulariae*, *C. tuberculosus* und *Cleopus pulchellus* aus der Curculioniden-Tribus Cionini wird beschrieben, die Präimaginalentwicklung, soweit möglich, dargestellt. Graphiken erläutern den Lebenszyklus, es werden Hinweise auf das Verhalten der Tiere gegeben. Die zeitliche Einnischung der Arten wird durch Schlupfkurven verdeutlicht. Die Ausnutzung und Verteilung der Rüßlerarten auf der Pflanze wird dargestellt; es erfolgt eine kurze Betrachtung der Konkurrenzverhältnisse. Die Parasitoiden der Cionini-Arten werden angegeben.

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